SIGNALS AND SYSTEMS MATLAB ASSIGNMENT

By - Jash Shah
Id - 2018A8PS0507P
T - 1 [Dr. Anantha Krishna Chintanpalli]

Submitted in partial fulfillment of the course SIGNALS AND SYSTEMS(INSTR F243)
on 15 April 2021

QUESTION 1

Q1 a) Generate a signal $x(t)$ with total duration of 5 ms (0 to 5 ms), in which the first 3 ms there is a single tone sinusoidal $x1(t) = 5cos(2\pi f t)$ and the last 2 ms of the total duration, the signal is zero. Use the sampling frequency (Fs) = 800 kHz and the frequency (f) of the signal is 1507 Hz.

Q1b) Now, a new signal $x1(t) = x(-t/2 + \boldsymbol{b})$ is generated, where $x(t)$ is the same as in 1a) and the constant $\boldsymbol{b}$ (in ms) is7.

Plot the signals $x(t)$, $x(t + b)$ and $x1(t)$ as a function of time. Show the results as subplots of 3x1

Solution -

-> **Matlab code**

This is question 1 of the MATLAB Assignment

1.a The question requires the creation of a custom wave with the given credentials:-

Sampling frequency = 800 kHz i.e number of time samples to be used are 800,000

```
sam_freq = 8e005;                    % represented in scientific notation

end_time = 5e-3;                               % Defining 5 ms.

true_sam_freq = sam_freq*end_time;                   % Ambient Sampling
frequency

t = linspace(0,end_time, true_sam_freq);
```

Frequency is last three digits of my Id. Hence. freq = 507 Hz (My Id is 0507)

```
f = 1507;
```

Defining the custom signal

```
x = zeros(1,true_sam_freq);

for i = 1:true_sam_freq

   if(t(1:i) < 3e-3)
```

```
        x(1,i) = 5*cos(2*pi*f*t(1,i));
    else
        x(1,i) = 0;
    end
end
```

```
b = 7e-3*(ones(1,true_sam_freq));                          % b is 7 ms.
new_t = t - b;
```

1.b

```
new_t_b = -2*(t-b);
```

Plotting the signal

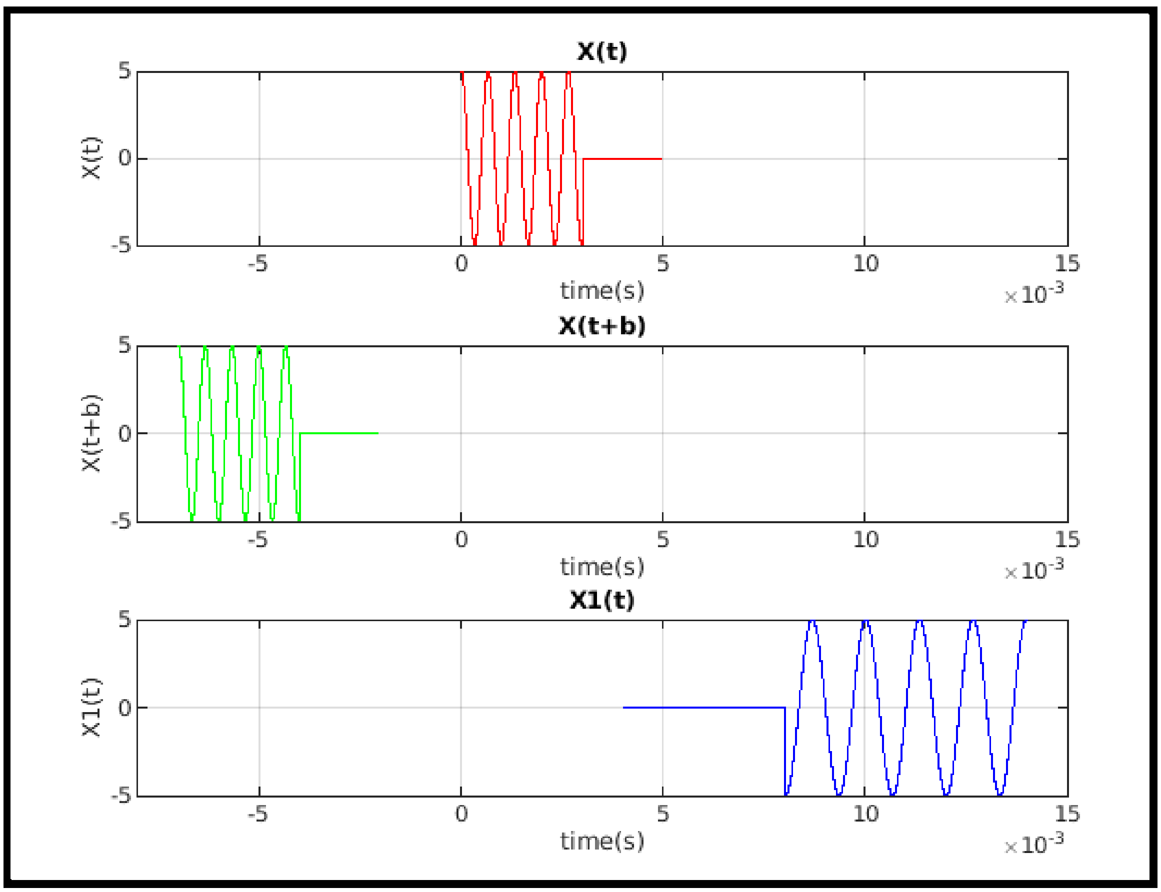
```
subtitle('Required signals');
```

```
subplot(3,1,1),plot(t,x,'r');
title('X(t)');
xlabel('time(s)');
ylabel('X(t)');
axis([-8e-3 15e-3 -5 5]);
grid on;
```

```
subplot(3,1,2),plot(new_t,x,'g');
title('X(t+b)');
xlabel('time(s)');
ylabel('X(t+b)');
axis([-8e-3 15e-3 -5 5]);
grid on;
```

```
subplot(3,1,3),plot(new_t_b,x,'b');
title('X1(t)');
xlabel('time(s)');
ylabel('X1(t)');
axis([-8e-3 15e-3 -5 5]);
grid on;
```

-> **Output Figure**



-> **Observations**

- x(t) is a combination of a sinusoidal (specifically cosine function) in the duration of 0-3 ms and is 0 from 4-5 ms. In any other time, the signal is not defined.
- The time shifted signal x(t+b) exists in the time t = -7 to t = -2 ms (and is thus not an observable signal in the real world).
- The signal x1(t) is yet a complex combination of time scaling, time reversal and time shifting and exists only in the time duration of t = 4ms to t = 14ms.
- The 3 signals are shown above, hence a comparison can be made between them and we can come to the conclusion that only x(t) and x1(t) are physically realizable.
- In the figure, the signals are drawn only in places where they exist.

------------X---------------------------X--------------------------X------------------------------X

QUESTION 2

Q2 A real signal $x(t)$ has its zeros at -2.5 and 2 and poles at 0, and $(-7 + j2)$, respectively. Draw the pole-zero diagram for the complete signal $x(t)$ in the s-plane. Identify which sided signal $x(t)$ would be if ROC had to include the right side of the pole located at 0? Justify your answer.

Solution -

-> **Matlab code**

This is Question 2 of the assignment

```
%sys = tf([5,1.5,7],[7,1.5,5]);

z = [-2.5, 2];

p = [0, -7+2i, -7-2i];

k = 1;

G = zpk(z,p,k);
```

Now plotting the pole-zero diagram.

```
len_p = length(p);

len_z = length(z);
```

```
for i = 1:len_p

   plot(real(p(1,i)),imag(p(1,i)),'bX')

   textString1 = sprintf('(%d, %d)', real(p(1,i)), imag(p(1,i)));

   text(real(p(1,i))-0.03, imag(p(1,i))+0.1, textString1, 'FontSize', 7);

   hold on

end
```

```
for j = 1:len_z

   plot(real(z(1,j)),imag(z(1,j)),'rO')
```

```
    textString2 = sprintf('(%d, %d)', real(z(1,j)), imag(z(1,j)));
    text(real(z(1,j))-0.03, imag(z(1,j))+0.1, textString2, 'FontSize', 7);
    hold on
end
```

```
grid on
title('Pole - Zero diagram')
```

Marking the co-ordinate axis for better view of stability.

```
x_abscissa = [-8 4]
y_abscissa = [0 0]
plot(x_abscissa,y_abscissa,'color', 'black')
xlabel('Real Axis')
```

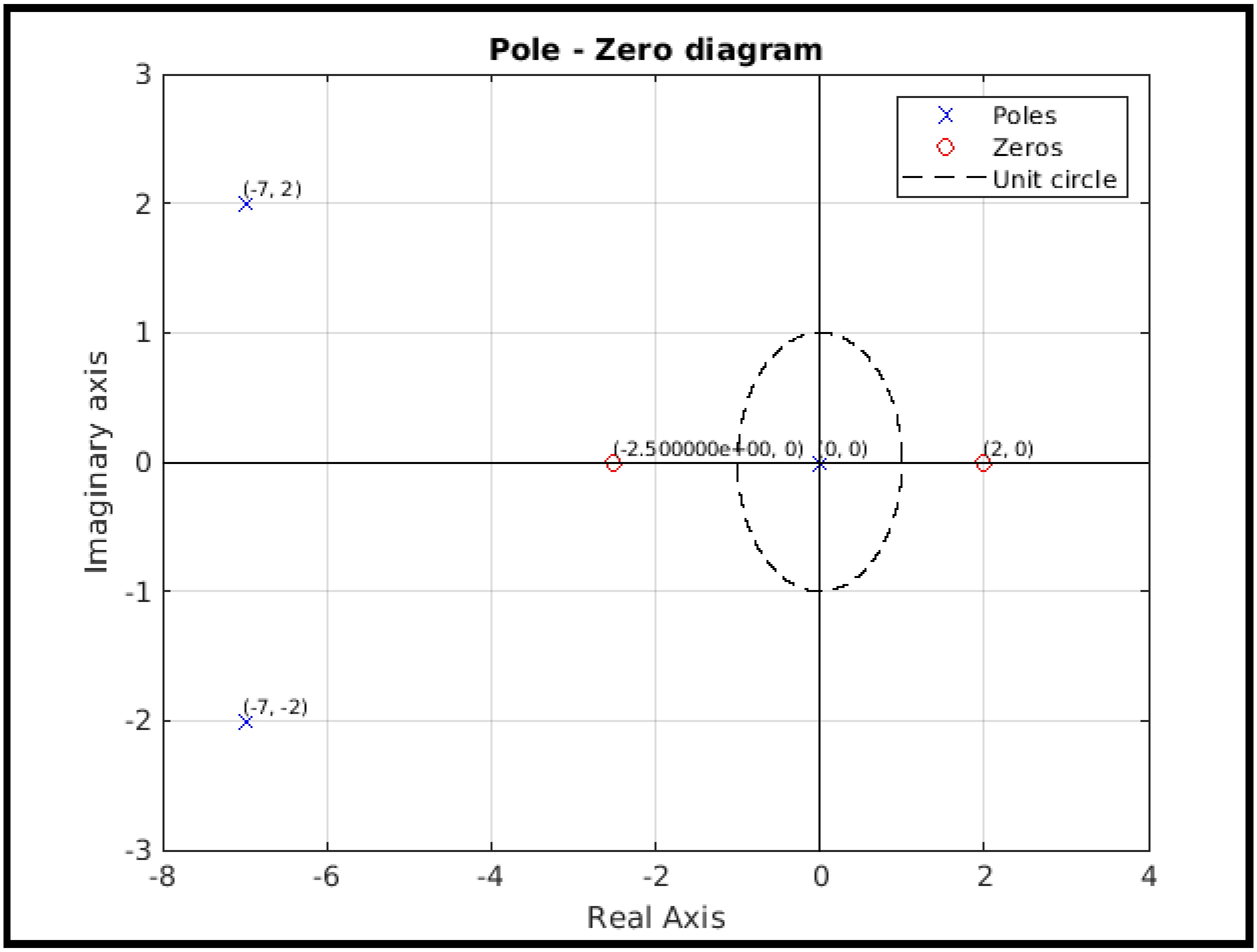
```
x_ord = [0 0]
y_ord = [-3 3]
plot(x_ord,y_ord,'color', 'black')
ylabel('Imaginary axis')
```

Creating the circles now

```
% for unit circle:
a = -pi:0.001:pi;
x_u_cir = cos(a);
y_u_cir = sin(a);
```

```
plot(x_u_cir,y_u_cir,'k--')
legend('Poles', '','','Zeros','','','','Unit circle');
hold off;
```

-> **Output Figure**



-> **Analysis**

If the ROC included Re(s) > 0, the system would definitely be a Right Handed system as it includes the positive plane of the s-domain.

Also, because there exists no pole beyond (0,0), it would not be a bounded ROC and hence we can be sure that the time-domain signal would be right handed.

-----------X-------------------------X-----------------------X--------------------------X

QUESTION 3

Q3 Compute the convolution of two rectangular pulses that are described below:

$x1(t) = u(t + 0.3) – u(t)$ and

$x2(t) = u(t + 0.5) – u(t – 0.7)$.

For $x1(t)$ and $x2(t)$, the time vector (t) = -1: 0.001: 1.

Plot $x1(t)$, $x2(t)$ and $y(t)$ as subplots of 3x1, where $y(t) = x1(t) * x2(t)$ and $*$ symbol denotes convolution.

Specify the XY coordinates (i.e., x and y values) wherever you observe any change in the shape of $y(t)$.

Solution -

-> **Matlab code : Special Function for Unit Step Impulse**

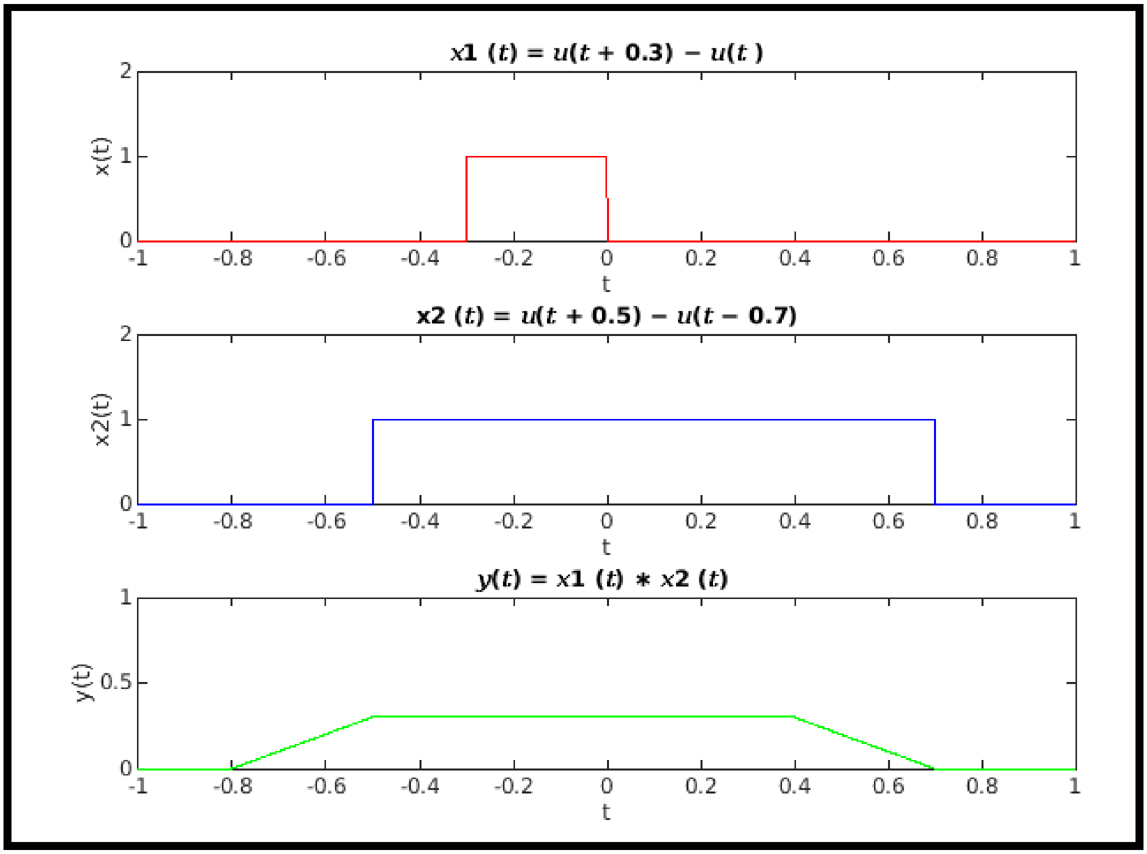
```
function[u] = u(t)
   len = length(t);
   u = zeros(1,len);
   for i = 1:1:len
       if t(1,i)>=0
           u(1,i) = 1;
       end
   end
end
```

-> **Matlab code : Main Script**

This is Q3 of the assignment

```
t = -1:0.001:1;
t_temp = -2:0.001:2;                    % For convolutional term
l = length(t);

x = u(t);

x1_t = t + 0.3*ones(l);
x1 = u(x1_t) - u(t);

x2_t_1 = t + 0.5*ones(l);
x2_t_2 = t - 0.7*ones(l);
x2 = u(x2_t_1) - u(x2_t_2);

y = conv(x1,x2)/1000;

subplot(3,1,1), plot(t,x1,'r'), title('x1 (t) = u(t + 0.3) − u(t
)'),ylabel('x(t)'), xlabel('t'), axis([-1 1 0 2]);
subplot(3,1,2), plot(t,x2,'b'),  title('x2 (t) = u(t + 0.5) − u(t − 0.7)'),
ylabel('x2(t)'), xlabel('t'), axis([-1 1 0 2]);
subplot(3,1,3), plot(t_temp,y,'g'), title('y(t) = x1 (t) ∗ x2 (t) '),
ylabel('y(t)'), xlabel('t'), axis([-1 1 0 1]);
```

-> **Output Figure**



-> **Observations**

- x1(t) and x2(t) are rectangular function of unequal lengths and thus, their convolution is trapezium of height 0.3

-> Points where y(t) is changing its shape

Point 1 -> (-0.803,0)

Point 2 -> (-0.501,0.3)

Point 3 -> (0.398,0.3)

Point 4 -> (0.699,0)

------------X--------------------------X-------------------------X------------------------------X

QUESTION 4

Q4 We need to design the 7th order Butterworth low-pass filter, whose cut-off frequency is 1 rad/sec. Determine the following:

(i) Draw the pole-zero diagram in the s-plane for the system function B(s) of the filter.

(ii) Draw the pole-zero diagram in the s-plane for the B(s)B(-s).

(iii)Compute the system function B(s). Note that your MATLAB code should display the expression for the system function and write down the same answer in your report.

Solution -

-> **Matlab code**

This is Q4 of the assignment

```
n = 7;
cutoff_freq = 1;                    % Wc
f = (1/cutoff_freq)/(2*pi);
```

```
[z,p,k] = butter(n,2*pi*f,'low','s');
[num,den] = zp2tf(z,p,k);
```

Part (i) of the assignment

```
len_p = length(p);
```

```
for i = 1:len_p
   plot(real(p(i)),imag(p(i)),'bX')
   textString1 = sprintf('(%d, %d)', real(p(i)), imag(p(i)));
```

```
   text(real(p(i))-0.03, imag(p(i))+0.1, textString1, 'FontSize', 7);
   hold on
end
```

```
grid on
title('Pole - Zero diagram of B(s)')
```

Marking the co-ordinate axis for better view of stability.

```
x_abscissa = [-8 4]
y_abscissa = [0 0]
plot(x_abscissa,y_abscissa,'color', 'black')
xlabel('Real Axis')
```

```
x_ord = [0 0]
y_ord = [-3 3]
plot(x_ord,y_ord,'color', 'black')
ylabel('Imaginary axis')
```

Creating the circles now

```
% for unit circle:
a = -pi:0.001:pi;
x_u_cir = cos(a);
y_u_cir = sin(a);
```

```
plot(x_u_cir,y_u_cir,'k--')
legend('Poles', '','','','','','','','','Wc circle');
hold off;
```

Part (ii) of the question

```
Bs = tf(num,den);
Bs_c = ctranspose(Bs);
x = Bs*Bs_c;
pzmap(x);
grid on;
hold on;
```

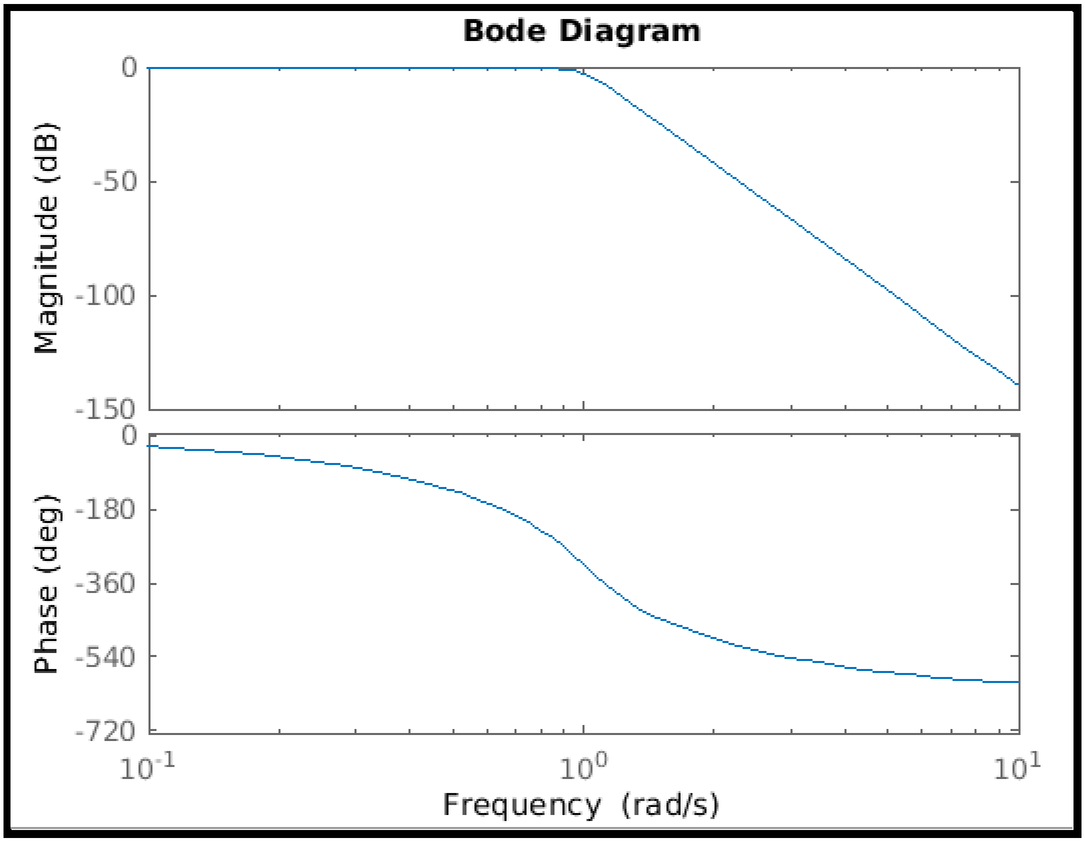
```
for i=1:n
   plot(real(p(i)),imag(p(i)),'bX')
   plot(-real(p(i)),-imag(p(i)),'bX')
end
a = -pi:0.001:pi;
x_u_cir = cos(a);
y_u_cir = sin(a);
plot(x_u_cir,y_u_cir, 'k--');
title('Pole - Zero diagram of B(s)B(-s)');
legend('','Pole','','','','','','','','','','','','','','Wc circle')
hold off;
```

Part (iii) of the question

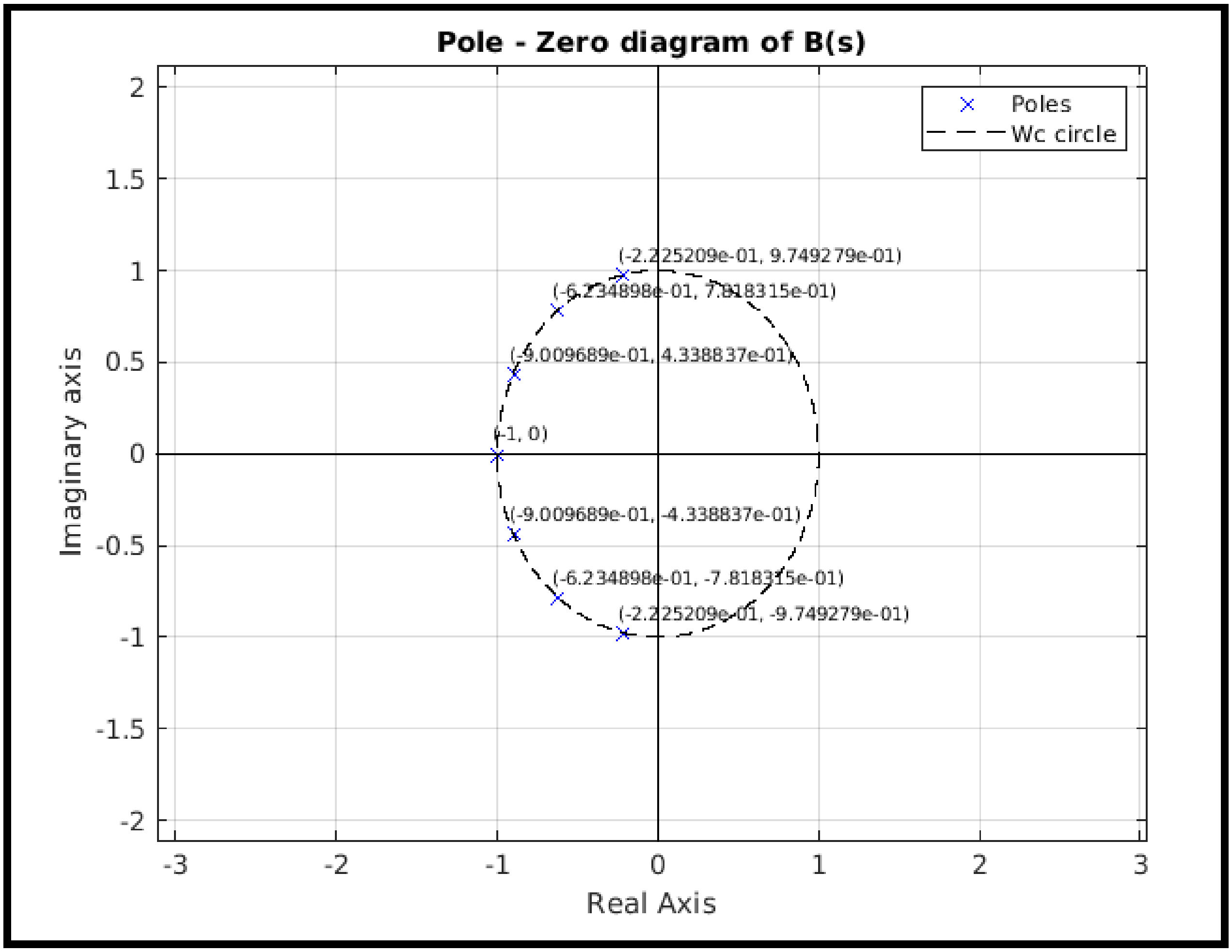
```
bode(Bs);
display(Bs);            % Transfer function
```

-> **Output Figures**

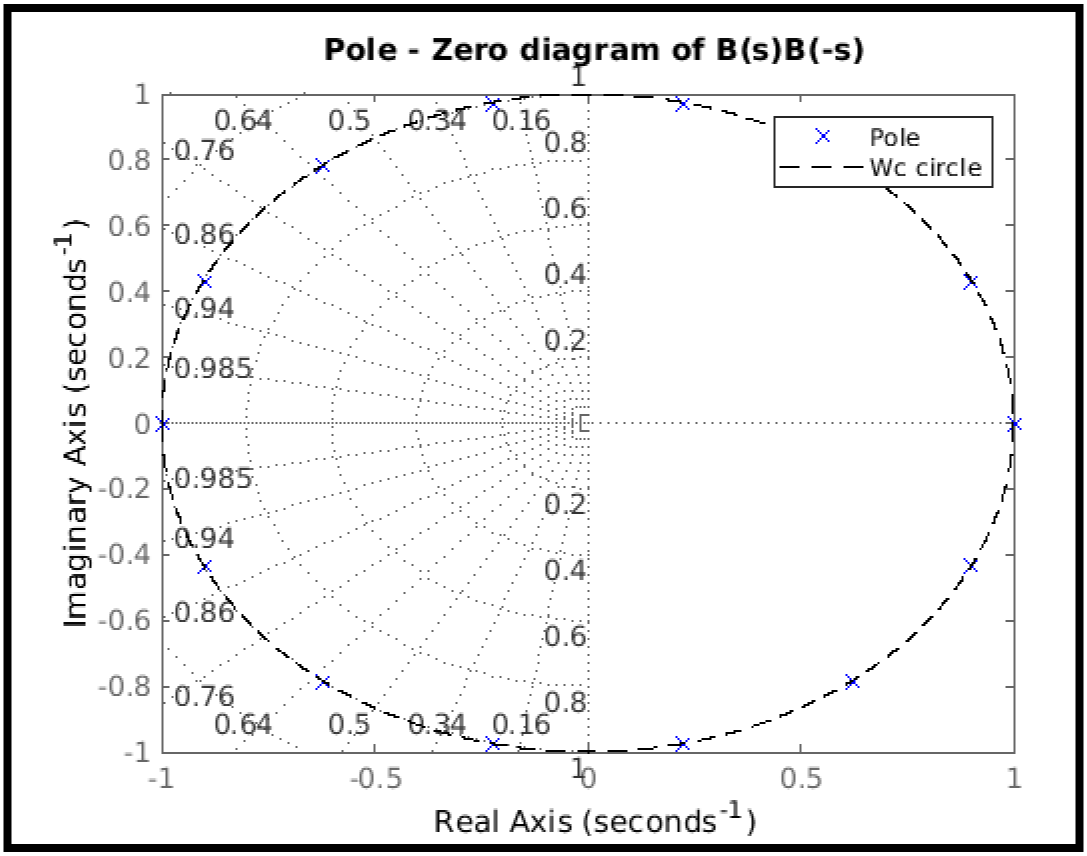
1. **Bode Plot of B(jw)**



2. Pole - Zero Diagram of B(s)



3. Pole - Zero Diagram of B(s)B(-s)



-> **Transfer Function of B(s)**

```
Bs =

                                    1
  ---------------------------------------------------------------------------
  s^7 + 4.494 s^6 + 10.1 s^5 + 14.59 s^4 + 14.59 s^3 + 10.1 s^2 + 4.494 s + 1

Continuous-time transfer function.
```